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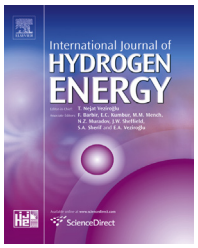

Establishing new model for predicting the global solar radiation on horizontal surface

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ABSTRACT

Solar radiation data and its components are one of the most important parameters for the system designed for solar energy applications in a certain region. In most cases, it is nearly impossible to find and measure solar radiation data. Thus, in places in which there is no solar radiation data, it is possible to determine solar radiation by carrying out a valid correlation. In this study, solar radiation models on the horizontal surface have been investigated to establish solar photovoltaic (PV) source for hydrogen generation in the near future and by making use of the data gathered from the meteorological measurement device (vantage PRO2) established in the university campus of Osmaniye Korkut Ata. As a result, a new model for the global solar radiation on horizontal surface for Osmaniye has been developed. Instantaneous global solar radiation on horizontal surface has been determined by using simple calculation method and a comparison of measured and calculated values has been made. Therefore, the best approach model in the estimation of global solar radiation has been determined. Moreover, with a view to show performance analysis of models, the statistical testing methods such as mean absolute percentage errors (MAPE), mean absolute bias error (MABE), root mean square error (RMSE) were used. The results reveal that a new model seems highly acceptable for predicting the solar radiation in Osmaniye.

Introduction

In the last two decades, solar energy has taken a significant place in many industries and application areas in terms of exciting electrons in a photovoltaic cell and supplying energy to natural processes like photosynthesis. As one of the most important renewable energies, solar energy has certain accessibility in many parts of the world such as building thermal systems and photovoltaic across the world. Renewable energy sources like solar, wind, geothermal and tidal are environmentally friendly, since they have a much lower environmental impact than conventional sources like fossil fuel. This kind of energy is free, clean and sufficient in many places in the world and is also important especially at the time of high fossil fuel costs and degradation of the atmosphere by the use of these fossil fuels. Among different kinds of renewable energy sources solar energy is considered as immense source, since it is ubiquitous. Solar energy is a non-depletable source that can provide abundant heat and

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electricity demands for a long time without polluting the air [1]. Renewable energy is accepted as a key source for the future, not only for Turkey but also for the world. This is primarily due to the fact that renewable energy resources have some advantages when compared to fossil fuels. At the present time, with existing technology, it is impossible to supply the total demand of any country from renewable resources [2]. However, environmental concerns and limited energy sources make renewable energy technology as a good candidate as fossil fuels. They are, in fact, complementary to each other and can be used effectively alone or in combinations of 2 or more renewable energy sources (e.g., wind and biomass). Thus, all renewable options should be pursued in tandem [3].

In recent years, hydrogen production from renewable energies is key to marking a gradual transition towards a clean hydrogen economy and a more sustainable and smart energy mix, in the present context of depletion of fossil fuels and their environmental, political and socio-economic impact on our modern societies [4]. Hybrid photovoltaic-fuel cell energy systems have been popular as energy production systems for different applications. A typical solar-hydrogen system can be modeled the electricity supplied by PV panels is used to meet the demand directly to the maximum extent possible. Solar-hydrogen systems and their application areas have been examined with emphasizing importance of renewable energy sources for electrical energy production. Thus, a hybrid system consists of solar cell and fuel cell have been designed and simulated in Matlab-Simulink [5]. Besides, the hydrogen generation system, using electrolysis and supplied by photovoltaic solar energy, and for which the power controller was also studied and was designed and tested by computer simulation [6]. Knowing solar energy radiation at any place is a key factor to design solar power generation with PV projects and develop a model for solar-hydrogen energy system. In this context, hydrogen production from different hybrid systems at various locations, such as wind–photovoltaic (PV) for the Ceara' state – Brazil [7] and Cooma (Australia) [8], PV and proton exchange membrane (PEM) electrolyser for Algeria [9], solar-hydrogen energy for Saudi Arabia [10] and Egypt [11], wind-solar-biomass for Argentina [12] water electrolysis with electricity from renewable sources, considering solar PV, wind and mini-hydro energy, all with large potential in Venezuela [13] and also for different techniques such as PV-water electrolysis technique [14] or hybrid power systems using renewable energy sources (wind/fuel cell/photovoltaic) [15] were investigated.

Measured solar radiation data or solar radiation model at a given location has to be known in order to obtain electricity with PV for hydrogen production. Therefore, solar radiation data and its components are one of the most important parameters for the system designed for solar - hydrogen energy production in a certain region. In addition to this, in the literature review, fuzzy logic, artificial neural network, mathematical linear and nonlinear functions about solar energy models have been investigated. Generally, five important research areas highlighted by researchers were reviewed by [16] and these research areas can be given as follows; a) improving efficiencies of solar thermal collector or PV/T systems, b) solar-based electricity generation by utilizing single or hybrid energy systems, c) solar hydrogen generation, d) solar energy utilization in zero energy or sustainable energy buildings, e) feasibility of solar energy utilization for many industrial applications like solar drying process. One of the most important requirements in the design and study of solar energy conservation devices is information on solar radiation and its components at a given location [17]. In other words, a reasonably accurate knowledge of the availability of the solar resource at any place is required by solar engineers, architects, agriculturists, and hydrologists in many applications of solar energy such as solar furnaces, concentrating collectors, and interior illumination of buildings [18]. On the other hand, the determination of solar energy capacity effectively, through the empirical models, plays a major role in developing solar energy technologies and the sustainability of natural resources [19]. In this sense, in the past several empirical formulas using various parameters have been tested in order to estimate the solar radiation all over the world. In this regard, the studies conducted on the evaluation of solar radiation measurements in Turkey may be classified in 4 groups as follows [20]: (1) developing empirical correlations for Turkey in general [21–24] (2) developing empirical correlations for some provinces of Turkey such as Istanbul, Gebze, Trabzon, Antalya, Izmir, Konya [19,25–28] (3) data use for estimating solar radiation and indicating the results graphically [29–31] and (4) other solar radiation studies such as estimation and statistical analysis of Angström equation coefficients, estimation of solar irradiation, determination of Turkey's monthly clearness index values and estimation of solar energy gain.

In this study, solar radiation models on the horizontal surface have been investigated to establish solar photovoltaic (PV) system for solar-hydrogen hybrid energy generation and by making use of the data gathered from the meteorological measurement device (vantage PRO2) installed in the university campus of Osmaniye Korkut Ata. So, a new model for the global solar radiation on horizontal surface in Osmaniye, Turkey has been developed. Nine different models have been compared with each other by using radiation data previously obtained. Instantaneous global solar radiation on horizontal surface of Osmaniye has been determined by using simple calculation method and a comparison of measured and calculated values has been conducted. Therefore, the best approach model in the estimation of global solar radiation on the horizontal surface of Osmaniye has been developed. Besides, with a view to showing performance analysis of models, the statistical testing methods such as mean absolute percentage errors (MAPE), mean absolute bias error (MABE), root mean square error (RMSE) were used.

Theory and analysis

Location, measurements and solar radiation data

Osmaniye, is one of the 81 provinces of Turkey, is located in the eastern Mediterranean region in Turkey and bordered by Gaziantep from east, Adana from west, Hatay from south and Kahramanmaras from north. Coordinates from the Northern Hemisphere are 37.05 north latitude and 36.14 east longitude. The altitude of Osmaniye above the sea level is 120 m and